09/890986
JC03 Rec'd PCT/PTC 08 AUG 2001

[001] ELECTRIC MACHINE

Ins a'

~~[002]~~

~~[003] The invention concerns an electrical machine, in particular, serving as an electric motor for a drive for vehicles in accord with the generic concept of Claim 1.~~

~~[004]~~

[005] Machines of this type are mostly asynchronous machines, which are constructed with a stator within which a rotor is provided. The rotor is designed to be of the squirrel cage type and is made preferably of electrically conductive aluminum, which is precision cast in a mold to the shape of the rotor. The aluminum, during the production, is poured into grooves formed by the laminate pack of the rotor. On the end of the rotor, the aluminum coils from the respective grooves are brought together into a ring thereby forming the said squirrel cage winding. The asynchronous motors are predominately run under heavy duty conditions and the heat generation by said motors calls for optimized cooling.

[006] Such a machine has been disclosed, for instance, by EP 0 484 548 B1. The electrical machines of this disclosed type possess an inward disposed rotor with a rotor shaft and a rotor laminate pack and an externally located stator. This electrical machine is connected with the cooling system of the vehicle.

[007] A particular problem with the cooling of such an electric machine is found in the bearing method to support the rotor shaft and in their sealing means. The heat transmitted from the rotor shaft to the bearings leads to bearing damage and, over time, to the failure of the machine. Because of high temperatures in the rotor shaft, large temperature differences consequently arise in the bearings between the inner bearing ring and the outer bearing ring. At the same time, circulation of a cooling medium in the electrical machine is made especially difficult by construction limitations presented by the machine.

[008] This leads to the fact that the generated temperatures, especially in the case of machines under heavy duty service, can not easily be conducted away from the internals.

[009] The present invention thus has the purpose of proposing an electrical machine, which makes a better transport of the cooling medium possible and protects the bearing of the machine from damage.

~~[010] This purpose is achieved in accord with the invention by the features of~~ Claim 1. Embodi~~ments of the~~ concept of the invention are described and explained ~~as objects of the subordinate claims.~~

Ins a2 ~~[011]~~

[012] For the purpose of cooling the machine, the heat generated by its operation must be transferred to a cooling medium. The medium must be easily transportable to the individual machine. Air is an advantageous cooling medium which itself, after such use, can be again cooled or exchanged for free air. Air is an excellent insulator, on its account, so that in an electrical machine, no special insulation means need be called upon in order to protect the various components of the machine against short circuit problems, which could arise from the characteristics of notice cooling medium. In order to conduct the cooling medium into the machine safely, possible flow restrictions must be avoided in every possible way.

[013] In accord with the invention, a cooling medium can be conducted through an area between a rotor laminate pack and a rotor shaft in an electrical machine which possesses an externally disposed stator, an inner, rotatably, bearing supported, hollow rotor, a laminated rotor pack, and a rotor shaft, connected to rotate with the laminate pack. For this purpose, the rotor shaft can be directly placed, in a rotational fixed manner, within the rotor laminate pack or, in an advantageous embodiment, a hollow interposed shaft may be inserted between the rotor laminate pack and the rotor shaft upon which shaft the rotor laminate pack is placed. Another embodiment shows the rotor shaft as a webbed shaft which possesses a plurality of webs on its circumference.

[014] In yet another advantageous embodiment, means are provided between the rotor shaft and the interposed shaft, i.e. the rotor laminate pack, to transport the

cooling medium. For this purpose, in one embodiment the rotor shaft possesses webs which are in the form of diffusor blades.

[015] One embodiment shows the rotor shaft designed in the shape of a screw conveyor. Another embodiment shows at least one ventilating apparatus located between the rotor shaft and the interposed shaft, i.e. the rotor laminate pack.

[016] Yet another embodiment shows the rotor shaft with ventilating apparatuses on at least one of its axial ends for increasing the transported volume or the pressure of the cooling medium. In another embodiment, the ventilating apparatuses on the end of the rotor shaft include a ventilating fan.

[017] In another embodiment, the rotor shaft is made separately as a forged component or is made by precision molding and pressed into the hollow interposed shaft, that is the rotor laminate pack, to achieve a force fit. In any case, the rotor is preferably made of a material of low heat conductivity and this material being advantageously a highly alloyed steel or titanium.

[018] In a favorable embodiment, the rotor shaft and the hollow interposed shaft, i.e. the rotor laminate pack, touch one another only by nearly linear contact zones for the purpose of forming minimum heat transmission surfaces. For this purpose, according to one method of the construction of a rotor shaft, the cross-section of said shaft is in the shape of a star with four points or webs, between it and an encompassing interposed shaft, which permits a large volume of cooling medium to pass between said rotor shaft and the interposed shaft, i.e. the rotor laminate pack. At the same time, this construction brings about sufficient structural strength. In yet another embodiment, the rotor shaft is designed with three sickle shaped webs so the construction of the rotor shaft will allow a high volume of cooling medium to flow between itself and the interposed shaft, i.e. the rotor laminate pack, and the formation of a large heat transfer surface with a simultaneous greater endurance to stress energy.

[019] A further embodiment shows elements for the support of a turbulence-free input of the cooling medium to the rotor. In this version, the webs are interrupted along the longitudinal contact and do not lie along their entire length against the hollow interposed shaft.

[020] In a further favorable embodiment, a heat exchanger is integrated into the electrical machine. The heat exchanger can have cooling tubes, which surround the stator and said cooling tubes can communicate, in a heat transfer manner, with provided cooling ribs. Cooling tubes can be provided directly within cooling ribs, which, with the cooling tubes which surround the stator, are inter-connectable. These cooling tubes embedded in the cooling ribs can, in one version, be installed at an angle to the cooling tubes which surround the stator. One embodiment shows the cooling ribs placed in a separate construction component, which can be mounted in the form of a cooling basin to the electrical machine.

[021] A preferred version employs air as the cooling medium.

Ins a3 ~~[022]~~

[023] The invention will be explained and described in greater detail with the help of the drawings in which:

[024] Fig. 1 is an electrical machine with a star shaped, webbed shaft,

[025] Fig. 2 is a cross-section through a webbed shaft an rotor shaft as in Fig. 1,

[026] Fig. 3 is a cross-section through the heat exchanger, as in Fig. 1,

[027] Fig. 4 is an electrical machine with a shaft having sickle shaped internal webs,

[028] Fig. 5 is a cross-section through a webbed shaft and rotor laminate pack of Fig. 4,

[029] Fig. 6 is an electrical machine with a ventilating apparatus in the rotor shaft,

[030] Fig. 7 is a cross-section through the webbed shaft and the rotor shaft of Fig. 6,

[031] Fig. 8 is an electrical machine with a webbing arranged as an internal screw coil,

[032] Fig. 9 is a cross-section through a heat exchanger which possesses a cooling basin,

[033] Fig. 10 is a further cross-section through a heat exchanger with a cooling basin,

[034] Fig. 11 is a cross-section through the cooling basin in accord with Fig. 9, and

[035] Fig. 12 is a cross-section through the cooling basin in accord with Fig. 10.

Ins. a4 ~~[036]~~

[037] Fig. 1 shows an electric machine 2 with a rotor shaft 4, which rotates on two sets of bearings, namely 6 and 8, which are enclosed in a housing 10. The rotor shaft 4 possesses a toothed end 11, proximal to the bearing, by means of which the electrical machine 2 coacts with additional (not shown) elements of a line of drive mechanism. A rotor, a stator laminated pack 12, through which a stator winding 14 penetrates is placed in the housing 10. A rotor laminate pack 18, separated by a spacer opening 16, is situated radially within said stator laminate pack 12. The rotor laminate pack 18 is penetrated by metal pins 20, which preferably are made of aluminum. A cap 24 is fastened onto the rotor laminate pack 18 with screws 22. As an alternative, the metal pins 20 can be embedded in the rotor laminate pack 18 in a precision molding operation. The rotor laminate pack 18 is seated on a hollow interposed shaft 26, circular in cross section. The rotor shaft 4 is placed with said interposed shaft 26 by press a fit, so that it rotates as one with the interposed shaft 26. The rotor shaft can, however, be press fit directly into the rotor laminate pack. The rotor shaft 4 possesses four webs 28, which are arranged in the shape of a star (see Fig. 2). The webs 28, in the embodiment depicted here, provide open spaces 29, so that the webs 28 do not lie along their entire length against the inner wall of the hollow interposed shaft 26. In the empty spaces 30, a first cooling medium, preferably air, can be circulated through the interposed shaft 26 between the webs 28, that is, for cooling the connected rotor laminate pack 18 thereto. For this purpose, a ventilating fan 32, which brings about a flow of the cooling medium, is placed on an axial end of the rotor laminate pack 18. A steel ring sheet 34, which directs the cooling medium flowing through a heat exchanger 36 in the direction of the interposed shaft 26, without turbulence, is provided on the other axial end of the rotor laminate pack 18. The heat exchanger 36 possesses cooling ribs 38 (see Fig. 3) through which the

cooling medium flows and, in the embodiment illustrated here, these are constructed integrally with part 40 of the housing. The outward extension of the cooling ribs 38 are limited by a cover 42 which is screwed onto the housing part 40.

[038] Cooling tubes 44, through which a second cooling medium flows, are provided in the housing part 40. The heat from the first cooling medium in the heat exchanger 36 which has been transferred by the cooling ribs 38 to the cooling tubes 44 is removed from the electrical machine 2 by the second cooling medium. At the same time, heat from the stator laminate pack 12 can be transferred to the cooling tubes 44, whereby cooling of the stator laminate pack 12 is effected.

[039] In the arrangement shown in Fig. 4, the electrical machine 2 exhibits a rotor shaft 4, which possesses three webs 46 bent into a sickle shape. This sickle shape, curving form enables a high operational loading in regard to the tensile energy to be assumed by the press fit of the webbed shaft 4 into the rotor laminate pack 18. For this purpose, settings and manufacturing tolerances can be evened out, that is, compensated for.

[040] The cooling tubes 48, in the embodiment shown here, are provided with a right angled cross-section. The bearing 50, which is constructed here as a roller bearing, possesses a grease cup placed within a cap 52.

[041] In Fig. 6, no webs at all are found within the interposed shaft 26, but rather ventilating apparatuses 54, whereby in the arrangement shown here, a device 54 is provided on each end of the interposed shaft 26. The inner ring 56 of the ventilating apparatus 54 is made by means of a toothed section 58 to turn as one, with the rotor shaft 4 (see Fig. 7). The outer ring 60 turns as one with the interposed ring 26 by means of a toothed section 62. The vanes 64 of the ventilating apparatus 54 transport the first cooling medium, again preferable air, through the hollow interposed shaft 26 which is integral with the rotor laminate pack 18. The contact surfaces for the exchange of heat between the interposed shaft 26 and the rotor shaft 4, in this case, are very limited.

[042] The embodiment shown in Fig. 8, exhibits a rotor shaft 4 which is shaped in the manner of a screw conveyor. The web winds around a central shaft and,

in this way can forward the first cooling medium through the internal hollow space of the interposed ring 26 upon rotation.

[043] Again in this case, the contact surfaces between the interposed shaft 26 and the rotor shaft 4 are in a quasi, line-like surface contact along the web so that the heat transmission can be held to a predominately low level. At the same time, as in all of the foregoing described embodiments, the material of the rotor shaft 4 is so chosen that poor heat transmission is assured. A high alloy steel content or titanium would be among such materials.

[044] In Figs. 9 to 12, different embodiments of the heat exchanger 36 are described. In Fig. 9, the cooling tubes 44 are arranged so that they are only embedded in the housing part 40 to the extent of a portion of their circumference. The other portion of the circumference radiates the heat in the direction of the cooling ribs 38, which are placed in a cooling basin 66, which is cooled from the outside. The cooling basin 66 is connected to the housing 10. Fig. 11 shows a cross-section through the heat exchanger 36 of Fig. 9. The cooling tubes 44 extend outward to approach the cooling ribs 38 so that the heat can be easily transferred. The cooling basin 66 is screwed onto the housing 10 by screws 68.

[045] Also in Fig. 10, the cooling tubes 44 are arranged so that only a portion of their circumferences are embedded in the housing part 40. The other part of the circumferential area radiates the heat present in the direction of the cooling ribs 38, which are placed in a cooling basin 66. The cooling basin 66 is connected to the housing 10. Cooling tubes 70, depicted here as dotted lines, are connected with the cooling tubes 44, which are to be found proximal to the cooling ribs 38. The cooling tubes 70 penetrate the cooling ribs 38 and cross the cooling tubes 44 at an angle of 90°. In this way, the cooling tubes 70 advantageously run through the cooling ribs 38 in a meander fashion and are connected with the cooling tubes 44 at the beginning and end. The cooling tubes 70 can also be carriers of a through low temperature cooling medium which is fed from a source outside of the motor.

[046] Fig. 12 shows a section through the heat exchanger 36 in accord with Fig. 10. The cooling tubes 44 extend so far as to approach closely the cooling ribs

38, so the heat can be easily extracted therefrom. The cooling ribs here form a separate cooler 72 which is placed in the cooling basin 66.

[047] The cooling tubes 70 penetratively run through the cooling ribs 38 whereby the flow of the second cooling medium, in every two adjacent cooling tubes 70, is in a counterflow state. The cooling basin 66 is screwed onto the housing 10 by fastening screw 68.

[048] The rotor and the stator can be constructed in a compact mode of construction and thereby a high utilization of the advantages of the machine can be attained. The electrical load data of the rotor in the invented machine are not affected. An advantageous aspect is the air intake proximal to the shaft center which provides generation of pressure for ventilation.

Reference numbers and items

2 electrical machine
4 rotor shaft
6 bearing (rotor shaft)
8 bearing (rotor shaft)
10 housing
11 toothed section of rotor shaft
12 stator laminate pack
14 stator winding
16 an air gap between 12 and 18
18 rotor laminate pack
20 metal bar or pin
22 screwed connection
24 cap for 18
26 interposed shaft
28 web
29 opening to minimize heat flow
30 open space for cooling Fig. 2
32 ventilating fan (wheel)
34 a ring of sheet steel
36 heat exchanger
38 cooling rib
40 housing part
42 cover
44 cooling tube
46 web
48 cooling tube
50 bearing (Fig. 4)
52 cap for bearing grease pot
54 ventilating (cooling_ apparatus
56 inner ring
58 Toothed zone, Fig. 6
60 outer ring
62 toothed zone, Fig. 6
64 diffusor blades, Fig. 7
66 cooling basin
68 screw connection
70 cooling tube
72 cooler (Fig. 12)